Commodore

The Transactor

comments and bulletins concerning your COMMODORE PET™

BULLETIN #11
April 30, 1979

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This months Transactor contains an excellent article by Brad Templeton on Pet interrupts. Also information on a PET to IBM selectric interface.

This is also the final issue of Volume 1. A subscription form for Volume 2 follows. When submitting the form, please address it to Commodore's Agincourt address followed by 'Attn. The Transactor'.

Transactor Volume 2

Yes it's renewal time. Although your Volume 1 subscription covers one more issue, here is the Volume 2 subscription form. The Transactor operates on a break-even basis. Therefore the cost of "The Transactor Volume 2" will be $15.00.

Recently I have received various requests regarding article subjects. If you have a subject idea you and other PET users would like to see discussed in future Transactors, please include it at the bottom of the order form.

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IDEAS & COMMENTS.....

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Convert Upper to Lower Case

The following is a program that will convert all upper case text to lower case. However, keep in mind that any graphics above the alphabetic keys will now be unusable if they are to appear simultaneously with lower case letters.

```
59030 FOR T=1024 TO 8006-FRE(0):A=PEEK(T)
59031 ON Z GOTO 59034,59037
59032 IF A=153 OR A=178 THEN Z=1
59033 NEXT
59034 IF A=34 THEN Z=2:NEXT
59035 IF A=58 OR A=0 THEN Z=0
59036 NEXT
59037 IF A 64 AND A 91 THEN POKE T,A+128
59038 B=PEEK(T+1):IF B=34 OR B=0 THEN Z=0
59039 NEXT:END
```

When writing the program use no spaces. The program will convert strings and PRINT statements but will not affect DATA statements. Also, it may terminate with a '?NEXT WITHOUT FOR ERROR IN 59036' but that's OK.

Of course you need not use the same line numbers. They were chosen due to their unusualness. The program was then recorded using the UNLIST routine in Transactor #7. It can then be merged with other programs with a good chance of <u>not</u> interfering with other program lines.

Karl J.

INTERRUPTS ON THE COMMODORE PET

(c) 1979 Brad Templeton

One of the most important features of the COMMODORE PET operating system is the use of interrupts. They are used to reset the PET, and they handle most of the tape and all of the keyboard i/o. This article will provide an introduction to interrupts on the 6502 (The PET's cpu) and a description of how the PET handles them. For your information, pseudo source listing is provided for the interrupt software of the PET, as produced by my disassembler.

Under normal conditions, a processor executes machine code in a linear fashion. It moves through memory, obtaining instructions (which can be one, two or three bytes long) and executing them. Sometimes, certain programmed instructions cause jumps to other places, just like GOTO and GOSUB of basic. To make a machine more flexible, however, interrupts are provided to do jobs that would be very expensive to do in software.

Essentially, an interrupt is controlled by a line right into the processor. When the processor detects the correct voltage on this line, an interrupt may be generated. First, in order to simplify matters, the processor finishes the instruction it is presently carrying out. Then, if the in-

terrupt is ok (interrupts can be masked). The processor saves the program location it was at, and the contents of its flags onto the stack. It then goes to a special reserved area of memory (in ROM on the PET) and pulls out two bytes indicating what location it should start executing from. It then goes there and executes machine code until the instruction RTI (Return from Interupt $40) is encountered. It then goes back to the stack and restores its flags, and loads the location it saved to the instruction counter. It then goes and executes the code after where it stopped as though nothing had occured. (If the interrupt program was correctly written)

On the 6502, three types of hardware interrupts can occur, as well as a fourth special type. The locations they branch to are kept in byte pairs called vectors at the end of memory. One of these interrupts, NMI or Non Maskable Interrupt, can not be used on the PET. Its vector, $FFFA-B, points to $CA60, which is the middle of a subroutine. The line for this is also fixed off by a resistor on the pc board. Later PETs may plan to include this.

The interupt called for power up is named RES. It branches to a routine which sets up basic and the operating system. It also, through what I consider to be one of the PET's worst design flaws, branches to the routine to destructively test how much memory is in the machine. At the very start, it also tests the condition of the diag-

nostic sense (MSB of $E810), and goes to the diagnostic routine if this is set. RES is fired by power up, or by grounding pin 27 on the bottom of your memory expansion bus. If you set it by touching that pin, it does not clear memory below $400, so programs there (the tape buffers) are safe. This is, unfortunately, a very small area. It vectors through $FFFC-D.

The general use, hardware inte upt is the IRQ. IRQ vectors through $FFFE-F, as does BRK. This points to location $E66B in the PET. It is generated every 60th of a second by the tv hardware, and can also be generated from the memory expansion bus, on pin 28. It is also connected to the 6522 versatile interface adaptor. I will discuss the 60 per second interrupts here in detail. For information of generation by the 6522 (there is another whole article's worth of material in there) you can write MOS® for the manual on it. Interrupts can be generated from it at exactly timed intervals, and by certain i/o conditions on the user port and IEEE bus. The exactly timed intervals are used to send precise frequency signals to the tape. (In fact, the 6522 is the PET's tape interface!)

The 60 per second interupts do the following:

Scan the keyboard, checking for new keys and decoding them.

Increment the real time clock, and check for midnight

Flash the cursor if it is on. ($0224 = 0)

Test tape recorder status for stop-start

Copy a byte for the break key test.

Whatever else you want them to do.

When the IRQ occurs, the code at $E66B (see source) saves the processor register A, X and Y on the stack. It then checks, by loading back from the stack, the flags, to see if the BRK flag was set. The BRK, a software IRQ, vectors through the same place, but sets the BRK flag. This is handy to test what type of interrupt occured. It then does a jump indirect to one of two places in RAM ($219 or $21B) depending on the type of interrupt.

Normally, the RAM IRQ vector is set to $E685, which is the standard IRQ code. BRK has no default setting. The small piece of code you see after the JMP indirects is the return code, which restores the registers and does the RTI. The first thing INT_CODE does is the JSR INCR_CLOCK which increments the clock and copies the PIA register the break key test uses. When Steve Punter of Mississauga saw this with the disassembler, he devised an ingenious way to disable the BREAK key of the PET. By telling the PET to branch to $E688 instead of $E685 by means of a POKE 537, 136 statement, the PET bypasses the INCR_CLOCK subroutine, and does not test the break key. (Note INCR_CLOCK passes through a JMP vector table in high ROM at $FFEA) This has the side effect of turning off the real time clock. When this statement is not used the clock proceeds normally. After it is updated, it is compared with a three byte table that con-

tains the value for midnight. If it is midnight on the clock, it is zeroed. The PET also keeps a secondary clock just after the main one. This is used for calibrating the real time clock. About every 6 seconds, this clock reaches a special limit, and when it does, it is zeroed, and the main clock is not incremented on this cycle. This is becuase the interrupt generator runs slightly faster than exactly 60 times per second. Even with this compensation, you may have noticed the clock is a few seconds off after several hours of PET operation. If they had used the 60 hz ac power line for the interupt, it would have been more accurate, but that would have caused problems for PETs sold abroad.

After doing the clock, it proceeds to flash the cursor, once every third of a second, if the location FLASHING ($224) is set to zero. (POKE 548,0 in a program turns the cursor on, but with some bugs - try it and see.) It does it with a very silly method that has no apparent purpose, instead of the standard method, a EOR $80. It then sets up two keyboard test locations.

In using your PET, you may have noticed that if the tape drive is stopped by the machine itself, that you can push stop and play and the motor will run again. This is handled by the section of code at $E6CD. After this comes the keyboard interpretation routines. The method of decoding the keyboard PIA has already been published in your

PET manual, and in PET user notes, so I will not dwell on it here. Once it has the matrix coordinate of the key, it waits for it to stabilize, to avoid bounce and repeating letters. (The TRS-80 does this poorly). It then converts the matrix number to an ascii character through the table at $E75C. (You can use this table in your programs, if you want to account for how long a key is held down - a great real time feature!) It then puts the key in the correct place in the keyboard buffer starting at $20F. Finally it goes back.

WHAT YOU CAN DO

Because the PET IRQ goes through RAM, it is one of the main links you have that can give you operating system control. You can insert your own programs before and after the interupt code to have your PET do two jobs at once, like handle i/o while running basic. I have used interupts to write programs to:

Interpret the PET keyboard and the full sized keyboard I attached to the PET like a regular keyboard.

Provide functions like repeat after a certain period of time and shift lock.

Turn the ! key to a statement number key, so that it would provide a line number 10 higher with every push.

Have upper case letter keys print out as full basic keywords.

Display whole pages of PET memory constantly on the screen.

Provide a non-destructive reset that works in special cases.

Much more is possible.

To use your own programs, you merely set them up in some convenient location (machine code only), preferably starting at location that ends in $85, such as $385 in the second tape buffer. Something located there can then be started with a POKE538,3 and stopped with POKE 538,230, rather than having to write a special machine language program that disables the interrupt with SEI, changes the locations, and enables the interrupt with CLI. You do not

need to disable if you are only changing one byte of the location. Put some code there and follow it with a JMP $E685. This way it does your code and proceeds on to do its own. If you put in the following series:

EE 50 80 4C 85 E6

starting at $385 (901 base 10), and initiate it with POKE 538,3 you will see a byte on the screen constantly increasing in "value", once every 60th of a second. The PET will also be doing everything else as usual. The following code:

A2 00 BD 00 00 9D 50 80 E8 D0 F7 4C 85 E6

will dump a page of memory on the screen constantly. You can poke 905 with the page you wish to examine. Try 0,1,2,4,31,232. It starts with page 0. When scanning page 0, move the cursor and see what happens.

While doing this, you may have noticed that there is no flicker whatsoever on the screen despite the massive amount of writing to it being done. (Far faster than BASIC printing). This is because the interrupt is fired by the screen scan signal, and the screen is doing nothing shortly after the interrupt goes. This is also why the flashing cursor will never "snow" the screen. You can store almost half a screen without "snow" this way.

Sometimes it is important to put code in after the interrupt code of the PET. This can be done by manipulation of the stack, and is necessary for programs like the statement

numberer or keyword printer I included in my list above. I have included some code you can put in to allow you to do this. >PROG means the high order byte of where your post interupt code starts and PROG is the low order byte. PCLO and PCHI are two locations for storing the correct pc you can use. The program works by altering the stack, so that the PET goes to your program when it RTIs. The second part of the program, which finishes your routine off (GOBACK) resets the stack and restores the proper program counter and machine registers. You should be able to have a lot of fun with it.

It should be noted that probably the only reason the IRQ vector is in RAM is that the PET does change it for tape i/o routines. There is a table of possible vectors starting at $FD28 in the rom, and the table ends with the standard vector $E685. If you ever change the high order byte of the IRQ RAM vector, you must reset it before tape i/o is done. If you don't, the PET will reset it anyway, but the tape i/o may not be done, and you may crash your PET.

Incidentally, the disassembler was written in the system language B (a very nice, much improved BCPL) here at the University of Waterloo where I go to school and work for the Mathematics Faculty Computing Facility. This article was also prepared and formatted on the same Honeywell 66/60. Many of the labels used in the disassembly were provided through the massive effort of examining the PETs ROMs done

by Jim Butterfield of Toronto. My next article for the Transactor will be on programming interactive games for the PET.

① The 6522 Data Sheets (24 pgs.) and other MOS publications are available through dealers.

Here is the code for the interrupts on the PET

```
E66B  48           INTERUPT   PHA
E66C  8A                      TXA
E66D  48                      PHA
E66E  98                      TYA
E66F  48                      PHA
E670  BA                      TSX
E671  BD 04 01                LDA   $104,X
E674  29 10                   AND   #$10
E676  F0 03                   BEQ   $E67B
E678  6C 18 02                JMP   [BRK_LOW]
E67B  6C 19 02                JMP   [IRQ_LOW]
E67E  68           RETURN_INT PLA
E67F  A8                      TAY
E680  68                      PLA
E681  AA                      TAX
E682  68                      PLA
E683  40                      RTI


E684  60                      RTS


E685  20 EA FF     INT_CODE   JSR   INCR_CLOCK
E688  AD 24 02                LDA   FLASHING
E68B  D0 23                   BNE   $E6B0
E68D  CE 25 02                DEC   C_TIMER
E690  D0 1F                   BNE   $E6B0
E692  A9 14                   LDA   #$14
E694  8D 25 02                STA   C_TIMER
E697  A4 E2                   LDY   C_COLUMN
E699  4E 27 02                LSR   C_STATE
E69C  B1 E0                   LDA   (C_ROWADR),Y
E69E  B0 06                   BCS   $E6A6
E6A0  EE 27 02                INC   C_STATE
E6A3  8D 26 02                STA   CHAR_UND_C
E6A6  0A                      ASL
E6A7  B0 03                   BCS   $E6AC
E6A9  38                      SEC
E6AA  B0 01                   BCS   $E6AD
E6AC  18                      CLC
E6AD  6A                      ROR
E6AE  91 E0                   STA   (C_ROWADR),Y
E6B0  A2 FF                   LDX   #$FF
E6B2  8E 23 02                STX   KEY_IMAGE
E6B5  E8                      INX
E6B6  8E 04 02                STX   SHIFT_FL
E6B9  A2 50                   LDX   #$50
E6BB  AD 10 E8                LDA   PIA1
E6BE  29 F0                   AND   #$F0
```

```
E6C0  8D 10 E8     STA  PIA1
E6C3  A0 00        LDY  #$0
E6C5  AD 10 E8     LDA  PIA1
E6C8  0A           ASL
E6C9  0A           ASL
E6CA  0A           ASL
E6CB  10 07        BPL  $E6D4
E6CD  8C 07 02     STY  C1_STAT
E6D0  A9 3D        LDA  #$3D
E6D2  D0 07        BNE  $E6DB
E6D4  AD 07 02     LDA  C1_STAT
E6D7  D0 05        BNE  $E6DE
E6D9  A9 35        LDA  #$35
E6DB  8D 13 E8     STA  PIA1_B4
E6DE  90 0A        BCC  $E6EA
E6E0  8C 08 02     STY  C2_STAT
E6E3  AD 40 E8     LDA  PORT_B
E6E6  09 10        ORA  #$10
E6E8  D0 0A        BNE  $E6F4
E6EA  AD 08 02     LDA  C2_STAT
E6ED  D0 08        BNE  $E6F7
E6EF  AD 40 E8     LDA  PORT_B
E6F2  29 EF        AND  #$EF
E6F4  8D 40 E8     STA  PORT_B
E6F7  A0 08        LDY  #$8
E6F9  AD 12 E8     LDA  KB_ROWIN
E6FC  CD 12 E8     CMP  KB_ROWIN
E6FF  D0 F6        BNE  $E6F7
E701  4A           LSR
E702  B0 05        BCS  $E709
E704  48           PHA
E705  20 3F E7     JSR  DECODE_KBD
E708  68           PLA
E709  CA           DEX
E70A  F0 08        BEQ  $E714
E70C  88           DEY
E70D  D0 F2        BNE  $E701
E70F  EE 10 E8     INC  PIA1
E712  D0 E3        BNE  $E6F7
E714  AD 23 02     LDA  KEY_IMAGE
E717  CD 03 02     CMP  KEY_DOWN
E71A  F0 20        BEQ  $E73C
E71C  8D 03 02     STA  KEY_DOWN
E71F  AA           TAX
E720  30 1A        BMI  $E73C
E722  BD 5B E7     LDA  $E75B,X
E725  4E 04 02     LSR  SHIFT_FL
E728  90 02        BCC  $E72C
E72A  09 80        ORA  #$80
E72C  AE 0D 02     LDX  KEYCOUNT
E72F  9D 0F 02     STA  KEY_BUFF,X
E732  E8           INX
E733  E0 0A        CPX  #$A
E735  D0 02        BNE  $E739
```

```
E737  A2 00              LDX  #$0
E739  8E 0D 02           STX  KEYCOUNT
E73C  4C 7E E6           JMP  RETURN_INT
E73F  BD 58 E7  DECODE_KBD LDA  $E758,X
E742  D0 07              BNE  $E74B
E744  A9 01              LDA  #$1
E746  8D 04 02           STA  SHIFT_FL
E749  D0 10              BNE  $E75B
E74B  C9 FF              CMP  #$FF
E74D  F0 0C              BEQ  $E75B
E74F  C9 3C              CMP  #$3C
E751  D0 05              BNE  $E758
E753  2C 11 E8           BIT  PIA1 + 1
E756  30 03              BMI  $E75B
E758  8E 23 02           STX  KEY_IMAGE
E75B  60                 RTS

E736  AD 05 02  UPDATE_CLK LDA  CLOCK_2
E739  69 01              ADC  #$1
E73B  8D 05 02           STA  CLOCK_2
E73E  90 03              BCC  $E743
E740  EE 06 02           INC  CLOCK_2 + 1
E743  C9 6F              CMP  #$6F
E745  D0 07              BNE  $E74E
E747  AD 06 02           LDA  CLOCK_2 + 1
E74A  C9 02              CMP  #$2
E74C  F0 26              BEQ  $E774
E74E  EE 02 02           INC  M_CLOCK + 2
E751  D0 08              BNE  $E75B
E753  EE 01 02           INC  M_CLOCK + 1
E756  D0 03              BNE  $E75B
E758  EE 00 02           INC  M_CLOCK
E75B  A2 00              LDX  #$0
E75D  BD 00 02           LDA  M_CLOCK,X
E760  DD 88 E7           CMP  $E788,X
E763  90 17              BCC  $E77C
E765  E8                 INX
E766  E0 03              CPX  #$3
E768  D0 F3              BNE  $E75D
E76A  A9 00              LDA  #$0
E76C  9D FF 01           STA  $1FF,X
E76F  CA                 DEX
E770  D0 FA              BNE  $E76C
E772  F0 08              BEQ  $E77C
E774  A9 00              LDA  #$0
E776  8D 05 02           STA  CLOCK_2
E779  8D 06 02           STA  CLOCK_2 + 1
E77C  AD 12 E8           LDA  KB_ROWIN
E77F  CD 12 E8           CMP  KB_ROWIN
E782  D0 F8              BNE  $E77C
E784  8D 09 02           STA  PIA_COPY
E787  60                 RTS
```

Here is the source for the post interrupt code program

```
START    LDA  $105,X        GET
         STA  PCLO          PROGRAM
         LDA  $106,X        COUNTER AND
         STA  PCHI          STORE IT
         LDA  PROG          PUT IN YOUR
         STA  $105,X        OWN CODE
         LDA  >PROG         LOCATION
         STA  $106,X
         JMP  $E685         DO NORMAL INTERUPT
         REM  THIS CODE GOES AFTER YOUR CODE, TO RETURN
GOBACK   LDA  PCHI          RESTORE
         PHA  OLD
         LDA  PCLO          LOCATION
         PHA
         TSX
         DEX                RESET
         DEX                STACK
         DEX
         DEX
         TXS
         JMP  $E65E         DO RTI
```

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